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Optimization of Seed Rate and Graded Levels of Nitrogen on Growth and Yield of Rice Fallow Finger Millet

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

Rice-fallow finger millet is gaining importance as a resilient and nutritious crop for improving productivity and profitability in residual moisture ecosystems. Optimising seed rate and nitrogen nutrition is essential for achieving higher growth and yield under rice-fallow conditions. A field experiment was conducted during the *rabi* 2025-26 season at the Agricultural College Farm, Naira, Andhra Pradesh, to evaluate the effect of different seed rates and nitrogen levels on the growth and productivity of finger millet. The experiment was laid out in a split-plot design with three replications. Four seed rates, *viz.*, 7.5, 10.0, 12.5 and 15.0 kg ha^{-1}, were assigned to the main plots, while three nitrogen levels, *viz.*, 45, 60 and 75 kg N ha^{-1}, were allotted to the subplots. The finger millet variety 'Indravathi' was used as the test crop. The results revealed that seed rate and nitrogen application significantly influenced plant height, dry matter production, yield and harvest index. Among the seed rates, 15.0 kg ha^{-1} recorded the highest plant height, tiller production (70.9 m^{-2}), dry matter

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accumulation, grain yield, straw yield and harvest index, and remained statistically comparable with 12.5 kg ha^{-1}. Lower values were observed with 7.5 kg ha^{-1}. Increasing nitrogen levels significantly improved crop growth and productivity. Application of 75 kg N ha^{-1} produced the highest plant height, tiller density, dry matter production, grain yield, straw yield and harvest index, whereas the lowest values were recorded with 45 kg N ha^{-1}. The interaction effects between seed rate and nitrogen level were significant for grain and straw yields. The treatment combination of 15.0 kg seed ha^{-1} with 75 kg N ha^{-1} (M_4S_3) recorded the highest grain and straw yields, while the lowest grain yield was obtained with 7.5 kg seed ha^{-1} and 45 kg N ha^{-1} (M_1S_1). The study concluded that a seed rate of 15.0 kg ha^{-1} combined with 75 kg N ha^{-1} was effective for improving the growth, biomass production and productivity of rice-fallow finger millet under the North Coastal Zone of Andhra Pradesh.

Keywords: Finger millet; rice fallow; seed rate; nitrogen level; plant height; tiller density; dry matter production; grain yield; straw yield; harvest index.

1. Introduction

Finger millet (*Eleusine coracana* L.) is an important *rabi* crop in India, commonly known as ragi, and belongs to the family Poaceae. It is among the ancient and nutritious crops grown in India. It withstands warming, water and nutrient stresses; hence, it is considered a climate-change-compliant crop (Gaikwad et al., 2024). Finger millet has been identified as one of the future smart food crops by FAO (Li & Siddique, 2018) because of its nutrient-rich and climate-resilient features. Moreover, it can produce reasonable yields at a relatively low cost of cultivation (Gupta et al., 2017). Agronomically, finger millet thrives in marginal environments with minimal external inputs, tolerates drought and short growing seasons, and adapts well to diverse soil conditions, making it highly suitable for low-input and climate-resilient farming systems (Kumar et al., 2022). The ability of finger millet to withstand extreme environmental conditions, such as drought, high temperatures and scanty rainfall, has made it one of the most important crops in dryland agriculture. In India, it is the leading small millet in terms of both area and production and is particularly prominent in Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh. Nationally, it is grown over an estimated area of 1.03 million ha, producing 1.30 million metric tonnes with an average productivity of 1336 kg ha^{-1} (Department of Agriculture & Farmers Welfare, 2024). In Andhra Pradesh, finger millet is cultivated over 0.27 lakh ha, with a production of 0.33 lakh tonnes and an average productivity of 1222 kg ha^{-1} (Directorate of Economics and Statistics, 2024).

Recent reviews and compositional studies further indicate that finger millet remains relevant for food and nutritional security because of its fibre, protein and mineral composition, while its adaptation to semi-arid and low-input production systems supports its inclusion in climate-resilient cereal diversification (Yasir et al., 2024; Teklu et al., 2024; Thakur et al., 2025). Recent review evidence also indicates that germination-based processing is being examined as one approach to enhance the food value of finger millet, which supports continued agronomic attention to this crop (Vanshika et al., 2025).

Seed rate plays a crucial role in determining plant population, canopy development, resource utilisation and, ultimately, crop productivity. An optimum seed rate ensures adequate plant stand and efficient utilisation of available resources, such as moisture, nutrients, light and space (Szemerits et al., 2025). Lower seed rates may result in poor crop establishment and reduced yield due to insufficient plant population, whereas excessively high seed rates can increase intra-specific competition and adversely affect crop growth and yield (Haarhoff & Swanepoel, 2022). Therefore, identifying an optimum seed rate is essential for achieving higher productivity under rice-fallow conditions.

Recent finger millet studies have also shown that plant spacing, crop geometry and establishment methods affect growth, yield attributes and economic returns, supporting the need to refine plant population through locally tested seed-rate recommendations (Tiwari et al., 2025; Naik et al., 2025).

Nitrogen is one of the most important nutrients required for crop growth and development. It is a major constituent of chlorophyll, amino acids, proteins and nucleic acids, and plays a vital role in photosynthesis, cell division and biomass accumulation (Wang et al., 2024). Adequate nitrogen supply promotes vigorous vegetative growth, enhances tillering, improves dry matter production and contributes to higher grain yield of finger millet. Under rice-fallow conditions, where crops largely depend on residual soil fertility and limited external inputs, optimisation of nitrogen application becomes critical for maximising nutrient-use efficiency and productivity

(Singh et al., 2022). Insufficient nitrogen supply may restrict growth and yield, while excessive application may not be economical and can lead to nutrient losses.

Recent evidence on finger millet nutrient management indicates that nitrogen and site-specific nutrient approaches can improve productivity and nutrient-use efficiency when aligned with crop and soil conditions (Gangothri et al., 2023; Ghosh et al., 2024; Pramanick et al., 2024; Warisa et al., 2025). In rice-fallow and rainfed systems, millet-based diversification has also been reported to improve system productivity and resource-use efficiency, suggesting that agronomic optimisation of finger millet can be important under residual-moisture ecosystems (Ramyasri et al., 2019; Pan et al., 2024).

1.1 Research Gap

Although seed rate and nitrogen nutrition are individually recognised as important determinants of crop establishment and productivity, information on their combined optimisation for direct-sown rice-fallow finger millet under the North Coastal Zone of Andhra Pradesh is limited.

1.2 Objective

The present study was undertaken to evaluate the effect of different seed rates and graded nitrogen levels on growth, biomass accumulation, yield and harvest index of rice-fallow finger millet.

2. Materials and Methods

The present field experiment was conducted during the *rabi* 2025-26 season at the Agricultural College Farm, Naira, Andhra Pradesh. The soil was loamy sand in texture, low in organic carbon (0.58%) and available nitrogen (272 kg ha^{-1}), high in available phosphorus (38.6 kg ha^{-1}) and medium in available potassium content (376 kg ha^{-1}), with a slightly alkaline reaction (pH 6.8). During crop growth, the maximum and minimum mean temperatures recorded during the crop period were 32.9 °C and 15.0 °C, respectively. The mean relative humidity during the forenoon and afternoon ranged from 81.6% to 71.5%, with an average of 76.6%, and bright sunshine hours during the crop growth period ranged from 0.7 to 5.9 h day^{-1}, with an average of 3.4 h day^{-1}. The experiment was laid out in a split-plot design with three replications. The main plots comprised four seed rates, i.e., M_1 (7.5 kg ha^{-1}), M_2 (10.0 kg ha^{-1}), M_3 (12.5 kg ha^{-1}) and M_4 (15.0 kg ha^{-1}), and the subplots comprised three nitrogen doses, *viz.*, S_1 (45 kg ha^{-1}), S_2 (60 kg ha^{-1}) and S_3 (75 kg ha^{-1}). Indravathi was selected as the test variety. The seeds were soaked in water overnight before sowing. Healthy and viable pre-germinated seeds with 93% germination were broadcast uniformly on 19 November 2025, by adopting four different seed rates as per the main-plot treatments. Because the crop was grown as a fallow crop on residual soil fertility, no manure or fertiliser was applied except N, which was applied as per the subplot treatments. To maintain optimum plant population, gap filling was done at 15 DAS and thinning was done at 20 DAS. Two hand-weedings at fortnightly intervals were carried out from 20 DAS to keep the plots free from weeds. The crop was grown on residual soil moisture up to 30 DAS, and thereafter three irrigations were given: the first at 30 DAS along with the first top-dressing of nitrogen (urea), the second at the flowering stage and the third at the grain-filling stage. Data on maximum plant height, number of tillers $plant^{-1}$, grain yield, straw yield and harvest index were recorded as per standard procedures. Data were analysed using ANOVA, and significance was tested using Fisher's least significant difference ($p = 0.05$).

3. Results and Discussion

With respect to seed rate, statistically significant differences were observed in plant height recorded at 30, 60 and 90 DAS and at harvest, and in the number of tillers m^{-2} recorded at 30 and 60 DAS and at maturity. The highest values were observed with a seed rate of 15.0 kg ha^{-1} at all stages of crop growth and were found to be on par with 12.5 kg ha^{-1}. Lower values were noticed with 7.5 kg ha^{-1}, which was inferior to the other seed rates. The higher plant height and number of tillers m^{-2} with 15.0 kg ha^{-1} might be attributed to increased competition among plants for sunlight under higher plant density, resulting in internode elongation and vertical growth. Increased plant density under higher seed rate could have enhanced resource utilisation, canopy development and vegetative growth, thereby promoting greater tiller initiation and production throughout the crop growth stages. These findings are in corroboration with those reported by Tiwari et al. (2025) in little millet, Hulakund et al. (2022) in browntop millet and Kujur et al. (2021) in finger millet.

Application of graded levels of nitrogen significantly influenced both plant height and number of tillers m^{-2} throughout the crop growth period. Among the nitrogen levels, application of 75 kg N ha^{-1} (S_3) recorded the highest plant height at 30 DAS, while 45 kg N ha^{-1} (S_1) resulted in the lowest plant height. At 60 and 90 DAS and at maturity, plant height under 75 kg N ha^{-1} (S_3) was found to be on par with 60 kg N ha^{-1} (S_2). Similarly, the number of tillers m^{-2} increased significantly with increasing nitrogen levels. The highest tiller production at 30 DAS, 60 DAS and maturity was recorded with 75 kg N ha^{-1} (S_3), which was statistically on par with 60 kg N ha^{-1} (S_2), whereas the lowest number of tillers m^{-2} was observed under 45 kg N ha^{-1} (S_1). These results indicate that higher nitrogen application promoted vigorous vegetative growth, resulting in increased plant height and tiller production compared with lower nitrogen levels. Similar results were reported by Gopi Krishna et al. (2025) in proso millet, and by Ghosh et al. (2024), Gangothri et al. (2023), Satya Sruthi and Umesh (2023) and Sanjana et al. (2020) in finger millet, including finger millet under rice-fallow conditions.

Dry matter production increased significantly with increasing seed rates and nitrogen levels at all stages of crop growth. Among the seed rates, the highest dry matter production was recorded with 15.0 kg ha^{-1} (M_4), while the lowest was observed with 7.5 kg ha^{-1} (M_1). At 60 DAS, M_4 remained superior and was statistically on par with 12.5 kg ha^{-1} (M_3). Similarly, increasing nitrogen levels enhanced dry matter accumulation, with 75 kg N ha^{-1} (S_3) producing the maximum dry matter, followed by 60 kg N ha^{-1} (S_2), while the minimum was recorded with 45 kg N ha^{-1} (S_1). At harvest, the significantly highest dry matter production was obtained with 15.0 kg ha^{-1} (M_4), and the lowest dry matter production was recorded with 7.5 kg ha^{-1} (M_1). With respect to nitrogen levels, the highest dry matter production was recorded with 75 kg N ha^{-1} (S_3), while the lowest dry matter production was obtained with 45 kg N ha^{-1} (S_1). The improvement in dry matter production under higher seed rates and nitrogen levels may be attributed to greater plant population, enhanced leaf area development, improved photosynthetic activity and better nutrient availability. However, the interaction between seed rates and nitrogen levels was non-significant at all growth stages, indicating their independent influence on dry matter production. These findings were in agreement with Pramanick et al. (2024), Ghosh et al. (2024) and Kujur et al. (2021) in finger millet, and Tiwari et al. (2025) in little millet.

The grain yield and straw yield of finger millet were significantly influenced by different seed rates and graded levels of nitrogen. Both parameters showed a gradual and progressive increase with increasing seed rate and nitrogen application, indicating the positive response of the crop to optimum plant population and adequate nutrient supply. Among the seed rates, the highest grain and straw yields were recorded with 15.0 kg ha^{-1} (M_4), which was statistically on par with 12.5 kg ha^{-1} (M_3) and significantly superior to the lower seed rates. The lowest grain and straw yields were observed under 7.5 kg ha^{-1} (M_1). Higher seed rates maintained optimum plant population, resulting in efficient utilisation of available resources such as nutrients, moisture, solar radiation and growing space. This enhanced vegetative growth, dry matter accumulation and yield attributes, ultimately contributing to increased grain and straw production. These results are supported by Tiwari et al. (2025) in little millet, Kujur et al. (2021) and Nigus and Melese (2018) in finger millet, and Gorini et al. (2023) in proso millet. With respect to nitrogen levels, application of 75 kg N ha^{-1} (S_3) produced significantly higher grain and straw yields compared with the lower nitrogen levels, while the lower yields were recorded with 45 kg N ha^{-1} (S_1). Adequate nitrogen availability enhanced chlorophyll formation, photosynthetic activity, protein synthesis and nutrient uptake, leading to vigorous crop growth, higher dry matter production and improved translocation of assimilates from source to sink. Consequently, greater grain and straw yields were achieved under higher nitrogen application. These findings were in agreement with Gopi Krishna et al. (2025) in proso millet, and Pramanick et al. (2024) and Ghosh et al. (2024) in finger millet.

The interaction effect between seed rate and nitrogen levels was also significant. The combinations of 15.0 kg seed ha^{-1} + 75 kg N ha^{-1} (M_4S_3), 15.0 kg seed ha^{-1} + 60 kg N ha^{-1} (M_4S_2) and 10.0 kg seed ha^{-1} + 75 kg N ha^{-1} (M_2S_3) recorded the highest grain yield, whereas the lowest yield was observed under 7.5 kg seed ha^{-1} + 45 kg N ha^{-1} (M_1S_1). The combinations of 15.0 kg seed ha^{-1} + 75 kg N ha^{-1} (M_4S_3) and 15.0 kg seed ha^{-1} + 60 kg N ha^{-1} (M_4S_2) recorded the highest straw yield, whereas the lowest straw yield was observed under 7.5 kg seed ha^{-1} + 60 kg N ha^{-1} (M_1S_2). The superior performance of M_4S_3 may be attributed to better crop establishment, optimum plant density, greater nutrient availability and enhanced nitrogen uptake, which promoted vigorous vegetative growth, higher dry matter accumulation and superior yield attributes. In contrast, the lower seed rate combined with the lower nitrogen level resulted in poor crop stand, inadequate nutrient availability and reduced growth, thereby lowering both grain and straw yields. Overall, increasing seed rate up to 15.0 kg ha^{-1} and nitrogen application up to 75 kg N ha^{-1} enhanced both grain and straw yields of finger millet by improving growth parameters, biomass production and efficient partitioning of photosynthates, demonstrating the beneficial effect of optimum seed density and adequate nitrogen nutrition on crop productivity.

Table 1. Growth parameters of rice fallow finger millet at 30, 60, 90DAS and at maturity as influenced by nitrogen levels and foliar sprays

Treatments	Plant height (cm)				Total Tillers (No.m^{-2})			Dry matter production (kg ha^{-1})		
	30	60	90	maturity	30	60	maturity	30	60	At harvest
M_1: 7.5 kg ha^{-1}	30.7	74.8	92.7	93.0	95.6	99.6	97.0	883	2363	4216
M_2: 10.0 kg ha^{-1}	33.8	82.2	102.2	102.9	114.1	119.7	116.7	944	2592	4870
M_3: 12.5 kg ha^{-1}	35.9	89.8	115.2	115.5	125.1	130.3	128.4	1030	2653	5220
M_4: 15.0 kg ha^{-1}	39.0	93.4	119.6	120.0	133.1	137.0	136.4	1120	2755	5528
Sem (±)	1.2	1.6	2.6	2.6	3.4	4.0	3.9	17.8	71.9	156.0
CD (P=0.05)	4.0	5.5	9.0	9.1	11.9	13.8	13.6	61.6	248.8	540
CV (%)	10.1	5.6	7.6	7.3	8.8	9.8	9.9	5.4	8.3	9.4
S_1: 45 kg ha^{-1}	33.2	77.8	103.4	103.6	109.5	112.0	109.0	952	2441	4348
S_2:60 kg ha^{-1}	34.1	86.8	107.9	109.2	119.3	124.4	121.8	997	2599	4951
S_3: 75 kg ha^{-1}	37.3	90.5	111.1	110.8	122.2	128.5	128.2	1034	2732	5577
Sem (±)	0.9	1.2	1.8	1.8	2.8	1.5	2.1	14.2	39.8	133
CD (P=0.05)	2.6	3.7	5.3	5.4	8.4	4.4	6.3	42.6	119.3	397
CV (%)	8.8	5.0	5.7	5.7	8.3	4.2	6.1	5.0	5.3	9.3
CD (P=0.05)	NS	8.7	13.2	NS	NS	15.7	17.7	NS	NS	904
CD (P=0.05)	NS	7.4	10.6	NS	NS	8.8	12.6	NS	NS	795

Harvest index of finger millet was influenced by seed rate and nitrogen levels. The highest harvest index (42.1%) was recorded with 15.0 kg seed ha^{-1} (M_4) and 75 kg N ha^{-1} (S_3), while the lowest harvest index (39.5%) was observed with 7.5 kg seed ha^{-1} (M_1) and 45 kg N ha^{-1} (S_1). Higher seed rate and nitrogen application improved dry matter production, photosynthetic activity and efficient translocation of assimilates towards grain formation, resulting in increased harvest index. Thus, optimum plant population and adequate nitrogen nutrition enhanced the conversion of total biomass into economic yield.

Table 2. Interaction effect of seed rate and graded levels of nitrogen on plant height (cm) at 60 DAS

Treatments	**Graded Levels of Nitrogen**			
Seed Rate	**S_1: 45 kg ha^{-1}**	**S_2: 60 kg ha^{-1}**	**S_3: 75 kg ha^{-1}**	**Mean**
M_1: 7.5 kg ha^{-1}	71.3	76.0	77.0	74.8
M_2: 10.0 kg ha^{-1}	76.7	84.3	85.7	82.2
M_3: 12.5 kg ha^{-1}	76.0	93.7	99.3	89.8
M_4: 15.0 kg ha^{-1}	87.3	93.3	100.0	93.4
Mean	77.8	86.8	90.5	
	S.Em(±)	CD (p=0.05)	CV (%)	
Seed rate (M)	1.6	5.5	5.6	
Graded levels of nitrogen (S)	1.2	3.7	5.0	
M*S	2.6	8.7		
S*M	2.5	7.4		

Table 3. Interaction effect of seed rate and graded levels of nitrogen on plant height (cm) at 90 DAS

Treatments	**Graded Levels of Nitrogen**			
Seed Rate	**S_1: 45 kg ha^{-1}**	**S_2: 60 kg ha^{-1}**	**S_3: 75 kg ha^{-1}**	**Mean**
M_1: 7.5 kg ha^{-1}	87.1	87.3	88.2	87.5
M_2: 10.0 kg ha^{-1}	83.3	98.9	102.9	95.0
M_3: 12.5 kg ha^{-1}	98.9	99.1	100.7	99.5
M_4: 15.0 kg ha^{-1}	97.5	104.9	107.2	103.2
Mean	91.7	97.5	99.7	
	S.Em(±)	CD (p=0.05)	CV (%)	
Seed rate (M)	2.8	9.5	8.6	
Graded levels of nitrogen (S)	1.4	4.2	5.0	
M*S	3.6	8.3		
S*M	2.8	12.1		

Table 4. Interaction effect of seed rate and graded levels of nitrogen on total tillers (No.m^{-2}) at 60 DAS

Treatments	**Graded Levels of Nitrogen**			
Seed Rate	**S_1: 45 kg ha^{-1}**	**S_2: 60 kg ha^{-1}**	**S_3: 75 kg ha^{-1}**	**Mean**
M_1: 7.5 kg ha^{-1}	96.0	101.3	101.3	99.6
M_2: 10.0 kg ha^{-1}	103.3	127.0	128.7	119.7
M_3: 12.5 kg ha^{-1}	120.7	134.7	135.7	130.3
M_4: 15.0 kg ha^{-1}	128.0	134.7	148.3	137.0
Mean	112.0	124.4	128.5	
	S.Em±	**CD (p=0.05)**	**CV (%)**	
Seed rate (M)	4.0	13.8	9.8	
Graded levels of nitrogen (S)	1.5	4.4	4.2	
M*S	4.6	15.7		
S*M	2.9	8.8		

Table 5. Interaction effect of seed rate and nitrogen levels on total tillers (No.m^{-2}) at maturity

Treatments	Nitrogen Levels			
Seed Rates	**S1: 45 kg ha^{-1}**	**S2: 60 kg ha^{-1}**	**S3: 75 kg ha^{-1}**	**Mean**
M1: 7.5 kg ha^{-1}	96.3	97.3	97.3	97.0
M2: 10.0 kg ha^{-1}	99.0	123.3	127.7	116.7
M3: 12.5 kg ha^{-1}	115.3	134.3	135.7	128.4
M4: 15.0 kg ha^{-1}	125.3	132.0	152.0	136.4
Mean	109.0	121.8	128.2	
	S.Em(±)	CD (p=0.05)	CV (%)	
Seed rate (M)	3.9	13.6	9.9	
Graded levels of nitrogen (S)	2.1	6.3	6.1	
M*S	5.2	17.7		
S*M	4.2	12.6		

Table 6. Interaction effect of seed rate and nitrogen levels on drymatter production (kg ha^{-1})

Treatments	Nitrogen Levels			
Seed Rates	**S1: 45 kg ha^{-1}**	**S2: 60 kg ha^{-1}**	**S3: 75 kg ha^{-1}**	**Mean**
M1: 7.5 kg ha^{-1}	2963	4317	5369	4216
M2: 10.0 kg ha^{-1}	4288	4741	5581	4870
M3: 12.5 kg ha^{-1}	4886	5335	5441	5220
M4: 15.0 kg ha^{-1}	5256	5411	5917	5528
Mean	4348	4951	5577	
	S.Em(±)	CD (p=0.05)	CV (%)	
Seed rate (M)	156	540	9.4	
Graded levels of nitrogen (S)	133	397	9.3	
M*S	267	904		
S*M	265	795		

Table 7. Interaction effect of seed rate and graded levels of nitrogen on number of tillers (m^{-2})

Treatments	Graded Levels of Nitrogen			
Seed Rate	**S_1: 45 kg ha^{-1}**	**S_2: 60 kg ha^{-1}**	**S_3: 75 kg ha^{-1}**	**Mean**
M_1: 7.5 kg ha^{-1}	53.0	55.7	56.7	55.1
M_2: 10.0 kg ha^{-1}	58.7	62.0	68.0	62.9
M_3: 12.5 kg ha^{-1}	64.0	66.7	65.7	65.4
$M_{4:}$ 15.0 kg ha^{-1}	61.3	71.3	80.0	70.9
Mean	59.3	63.9	67.6	
	S.Em(±)	CD (*p*=0.05)	CV (%)	
Seed rate (M)	1.3	4.6	6.2	
Graded levels of nitrogen (S)	1.0	3.1	5.7	
M*S	2.2	7.3		
S*M	2.1	6.2		

Table 8. Yield and harvest index of finger millet influenced by seed rate and nitrogen Levels

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
M_1: 7.5 kg ha^{-1}	1736	2673	39.5
M_2: 10.0 kg ha^{-1}	2041	2824	41.7
M_3: 12.5 kg ha^{-1}	2107	3007	41.9
M4: 15.0 kg ha^{-1}	2144	3205	42.1
SEm (±)	70	75	-
CD (P=0.05)	243	259	-
CV (%)	10.5	7.7	-
S_1: 45 kg ha^{-1}	1842	2777	39.9

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
S_2: 60 kg ha^{-1}	2016	2934	40.8
S_3: 75 kg ha^{-1}	2063	3071	41.2
SEm (±)	37	60	-
CD (P=0.05)	112	180	-
CV (%)	6.4	7.1	-
CD (P=0.05)	315	418	-
CD (P=0.05)	223	360	-

Table 9. Interaction effect of different seed rates and graded nitrogen levels on crop yield (kg ha^{-1})

Treatments	Nitrogen Levels			
Seed Rates	**S1: 45 kg ha^{-1}**	**S2: 60 kg ha^{-1}**	**S3: 75 kg ha^{-1}**	**Mean**
M1: 7.5 kg ha^{-1}	1687	1728	1792	1736
M2: 10.0 kg ha^{-1}	1886	2047	2189	2041
M3: 12.5 kg ha^{-1}	2009	2018	2294	2107
M4: 15.0 kg ha^{-1}	1784	2271	2377	2144
Mean	1842	2016	2163	
	S. Em (±)	CD (p=0.05)	CV (%)	
Seed rate (M)	70	243	10.5	
Graded levels of nitrogen (S)	37	112	6.4	
M*S	93	315		
S*M	74	223		

Table 10. Interaction effect of seed rate and nitrogen levels on stover yield (kg ha^{-1})

Treatments	Nitrogen Levels			
Seed Rates	**S1: 45 kg ha^{-1}**	**S2: 60 kg ha^{-1}**	**S3: 75 kg ha^{-1}**	**Mean**
M1: 7.5 kg ha^{-1}	2860	2519	2641	2673
M2: 10.0 kg ha^{-1}	2532	2912	3063	2835
M3: 12.5 kg ha^{-1}	2783	2984	3255	3007
M4: 15.0 kg ha^{-1}	2935	3320	3360	3205
Mean	2777	2934	3080	
	S. Em (±)	CD (p=0.05)	CV (%)	
Seed rate (M)	72	251	7.4	
Graded levels of nitrogen (S)	60	179	7.1	
M*S	121	411		
S*M	119	358		

4. Conclusions

The study showed that seed rate and nitrogen level influenced the growth and productivity of rice-fallow finger millet under the conditions of the experiment. Increasing the seed rate from 7.5 to 15.0 kg ha^{-1} improved plant height, tiller production, dry matter accumulation, grain yield, straw yield and harvest index. The performance of 15.0 kg ha^{-1} was generally superior and remained comparable with 12.5 kg ha^{-1} for some growth and yield parameters. Nitrogen application also improved crop performance, with 75 kg N ha^{-1} producing higher growth and yield values than 45 and 60 kg N ha^{-1}. The interaction between seed rate and nitrogen level was important for yield, and the combination of 15.0 kg seed ha^{-1} with 75 kg N ha^{-1} recorded the highest grain and straw yields. These results suggest that maintaining an adequate plant population with sufficient nitrogen supply can improve biomass production and economic yield of rice-fallow finger millet. Since the study was conducted during one season at one location, further testing across seasons and soil conditions is needed before wider recommendation.

5. Limitations

The study was conducted during a single rabi season at one experimental location, and the results may therefore be influenced by the specific soil, weather and residual moisture conditions of the site. Only one finger millet variety, Indravathi, was evaluated, so varietal differences in response to seed rate and nitrogen level were not assessed. Further multi-location and multi-season trials with additional varieties, economic evaluation and nutrient-use efficiency analysis are required to validate the optimum seed rate and nitrogen level for wider recommendation.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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